Comparison of SSM/I-derived Sensible and Latent Heat Fluxes and Aircraft-Measured Turbulent Heat Fluxes Over the Japan/East Sea During Cold Air Outbreaks

Bernard A. Walter
Northwest Research Associates
P. O. Box 3027
Bellevue, WA 98009
phone: (425) 644-9660, x-320; fax: (425) 644-8422; e-mail: walter@nwra.com

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http://www.onr.navy.mil/sci_tech/ocean/onrpgabv.htm

LONG-TERM GOALS

To develop a methodology for estimating latent and sensible heat fluxes from the ocean using satellite remote sensing data.

OBJECTIVES

The objectives of the proposed research are:

- to use algorithms developed for estimating latent and sensible heat fluxes from SSM/I data during cold air outbreaks over the Labrador Sea to make similar flux estimates for the Japan/East Sea (JES) during the ONR JES field program in February 2000; and,

- to compare the SSM/I flux estimates to in situ area-averaged turbulent sensible and latent heat flux measurements made by an instrumented aircraft over the JES by Dr. Carl Friehe during the ONR Japan/East Sea field program.

APPROACH

The algorithms developed during the Labrador Sea program use SSM/I brightness temperature data to provide areal estimates of surface wind speed, and integrated water vapor (IWV). Relationships were then developed between the IWV estimates and the surface mixing ratio and also surface air temperature using in situ data data from the Labrador Sea field program. With this information, and a value of the sea surface temperature, we then use the bulk flux formulations to estimate values of both the latent and sensible heat fluxes.

Here we compare the flux estimates obtained from the SSM/I algorithms to low level turbulent flux measurements made by Dr. Carl Friehe using the instrumented CIRPAS Twin Otter aircraft as part of the Winter 2000 Japan East Sea (JES) experiment. The aircraft was instrumented with wind, temperature, humidity, IR sea surface temperature and aircraft motion and navigation sensors. Data were recorded at a rate of 40 Hz for turbulent eddy correlation flux calculations.

Thirteen research flights were flown from Misawa NAF, Japan over the JES in cold air outbreak conditions on: January 30 and 31; February 2, 8, 9, 11, 14, 16, 17, 20, 21, 24 and 27. The purpose of the flights was to measure the surface fluxes and their spatial variability during cold air outbreak conditions. We will compare the aircraft surface fluxes with those estimated from the SSM/I data for each of the flights in order to assess the accuracy of the SSM/I technique.

We will use individual swath SSM/I brightness temperature data from the F13 DMSP satellite during the time period of the experiment at times closest to the aircraft measurements. The Labrador Sea algorithms were originally developed using the F13 data so we felt that the comparisons would be more valid if we used data from that satellite for the JES calculations. There is both a local morning and evening pass from the satellite.

The brightness temperatures were extracted for the locations of the aircraft flux measurements for each of the flights. The data set was screened for bad and missing data. These brightness temperatures were then used to calculate values of surface wind speed and IWV, and then from these, values of (q_s - q_a) (the difference in the saturation and actual mixing ratio at the surface) and T_a, the surface air temperature, over the JES using the Labrador Sea algorithms.

WORK COMPLETED

Turbulent flux data collected by the CIRPAS Twin Otter have been obtained from Dr. Carl Friehe at the University of California-Irvine for two flights during the JES field program. The flights were on February 17-18 and 21-22, 2000. The first flight was an internal boundary layer growth pattern that included eleven low-level crosswind flux runs going downwind across the Japan East Sea. The first run was at 42.218 deg N, 132.146 deg E. The final run was at 37.541 deg N, 137.791 deg E. The magnitude of the total (sensible plus latent) heat flux varied from a minimum of 175 to a maximum of 443 W/m^2.

The second flight was a flux mapping pattern that included eleven low-level flux runs near 41-42 deg N, 132 deg E. The magnitude of the total (sensible plus latent) heat flux varied from a minimum of 175 to a maximum of 220 W/m^2.

SSM/I brightness temperature swath data from the F13 satellite for February 17-18 was extracted over the JES from tapes received from Remote Sensing Systems (RSS), Inc. There were significant problems in decoding the tape due errors in software supplied by RSS, but we were finally able extract the brightness temperatures. Two satellite passes were available that essentially bracketed the flight time period. One pass was on February 17 at 1200 UTC and the second on February 18 at 1200 UTC. The flight was at 00-04 UTC on the 18th.

RESULTS

The SSM/I brightness temperatures were used to generate maps of surface wind speed and integrated water vapor (IWV). Table 1 shows the average wind speed measured by the aircraft at each stack pattern and the average wind speed computed from the brightness temperatures from both of the SSM/I passes bracketing the time of the flight. Also shown for comparison is the average wind speed computed using another algorithm published by Claud et al., (1992).

Table1. Comparison of the aircraft measured wind speeds with SSM/I-derived wind speeds using both the Labrador Sea and the Claud et al. (1992) algorithms for February 17-18, 2000.

Stack	Latitude, Deg N.	Longitude, Deg E.	Speed, m/s	Direction, deg	Average SSM/I speed, m/s Lab Sea algorithm	Average SSM/I speed, m/s Claud et al algorithm
1	42.22	132.15	13.3	336	7.2	10.7
2	41.69	132.83	15.9	324	9.0	12.4
3	41.22	133.45	16.5	315	9.4	12.8
4	40.74	134.05	14.1	306	10.0	13.2
5	40.28	134.62	12.8	303	10.3	13.4
6	39.82	135.18	12.2	305	11.3	14.5
7	39.37	135.71	12.1	300	11.8	15.5
8	38.90	136.24	11.8	303	12.2	16.0
9	38.43	136.79	13.5	293	12.3	15.9
10	37.96	137.32	13.2	305	11.6	15.4
11	37.54	137.70	14.3	306	12.5	17.3

As can be seen, the Labrador Sea wind speed algorithm considerably underestimates the speed over the first part of the aircraft run, but is quite close to the measured values over the second half of the runs. The Claud et al. (1992) algorithm also has low winds for the first part of the flight pattern but is closer than the Labrador Sea algorithm, but the winds at the locations over the second half of the runs are much higher than the measured values. A closer look at the results will be needed to determine the origin of these differences.

The values of the integrated water vapor (IWV) from both the Labrador Sea algorithm and that given in Claud et al (1992) were very close.

We next computed: values of ($q_a - q_s$) from the SSM/I algorithm; the predicted values of the surface air temperature from the SSM/I algorithm; and finally the surface sensible and latent heat fluxes using the SSM/I algorithms and compared these to the aircraft measured fluxes. This comparison is shown in Table 2.

Table 2. Comparison of values of aircraft-measured and SSM/I-estimated: air temperature, latent heat flux and sensible heat flux.

Stack	**Aircraft** measured **air temperature**, Deg C	**SSM/I** estimated **air temperature**, Deg C	**Aircraft** measured **latent heat flux**, W/m^2	**SSM/I** estimated **latent heat flux**, W/m^2	**Aircraft** measured **sensible heat flux**, W/m^2	**SSM/I** estimated **sensible heat flux**, W/m^2
1	-8.8	-7.1	123	54	111	63
2	-7.8	-5.2	178	68	172	63
3	-6.6	-5.0	104	89	113	82

4	-5.5	-3.9	84	88	91	74
5	-4.6	-4.4	116	114	136	104
6	-3.9	-3.3	117	117	116	97
7	-2.9	-3.3	164	166	200	153
8	-1.5	-2.2	114	157	165	132
9	-0.8	-3.3	183	194	260	185
10	+0.5	-2.5	136	194	282	180
11	+1.2	-3.4	149	214	198	208

The comparison of SSM/I-estimated fluxes with the aircraft fluxes for the February 17 case (Table 2) shows that the SSM/I latent heat fluxes are significantly lower than the aircraft fluxes for the first third of the flight track, in good agreement for the middle part and larger for the points near the southern coast. The SSM/I sensible heat fluxes are also significantly lower than the aircraft fluxes over the first part of the flight path, in better agreement over the middle third and generally lower over the latter part (except for the last point). The reasons for these disagreements will take more detailed analysis, but at first glance a key factor in the lower fluxes over the first third of the flight is the much lower wind speeds produced by the SSM/I wind speed algorithm than were actually present (Table 1). Other possible factors include incorrect values of the transfer coefficients.

The values of the SSM/I wind speeds, air temperatures and fluxes shown in Tables 1 and 2 were obtained by averaging, for each of the two SSM/I passes used, values closest to the aircraft leg, and then averaging the two pass values since the two passes bracketed the actual time of the aircraft flight. A more accurate method might have been to initially do, for each pass, a bilinear interpolation of the SSM/I brightness temperature values from the pixels nearest to the position of the aircraft leg and then use these interpolated brightness temperatures to calculate the wind speed, IWV, air temperature and the fluxes. This approach will be tried next. Also, a comparison will be done of the actual (q_s-q_a) values from the aircraft measurements and the values of (q_s-q_a) estimated from the SSM/I data.

IMPACT/APPLICATIONS

If this method of remotely estimating surface turbulent sensible and latent heat flux fields proves robust it would provide a method for supplying data for initializing oceanographic numerical models, and for the analysis/interpretation of oceanographic measurements. Having these higher resolution (~50 km) flux fields is critical for studying the scales of oceanographic processes important for ocean convection in the JES.

TRANSITIONS

It is too early in the project for transitions to other areas.

RELATED PROJECTS

In carrying out this work we will collaborate with Drs. Carl Friehe at Univ. of California-Irvine, Clive Dorman at UCSD and Qing Wang at the Naval Postgraduate School.

REFERENCES

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